Content-Aware Optimization of Tiled 360° Video Streaming Over Cellular Network

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Contents

Introduction

- 360° videos, also known as immersive videos or spherical videos, are video recordings where a view in every direction is recorded at the same time.
- 360° video playback provides 3-degree of freedom.

Fig. 360° Video EQR Projection.

Introduction

- Field of View (FoV) is an area observable by the user at any instance.
- In comparison to a planar 4K video, a 360° videos may require up to 10x bandwidth to achieve the same quality in FoV.
- To achieve 4K resolution in FoV, a 360° video of *12K* x *6K* resolution is required.

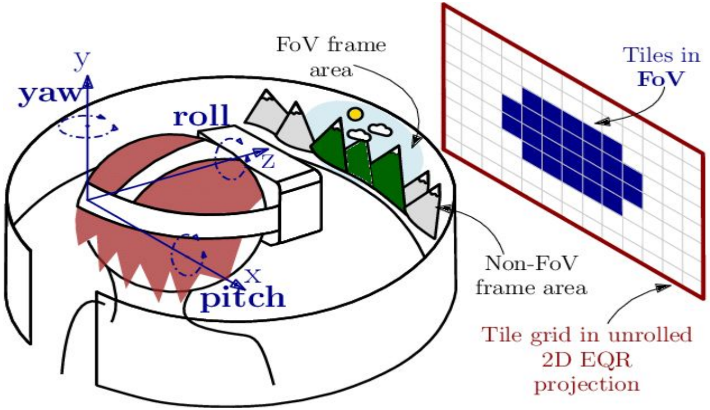

Fig. Users' Field of View (FoV)[2].

[1] Perfecto, Cristina et.al., "Taming the latency in multi-user VR 360°: A QoE-aware deep learning-aided multicast framework", TCOMM 2020.

Problem Statement

- User only sees FoV part of the frame, so fetching the complete spherical frame wastes the bandwidth.
- Existing methods (FoV-only[3], FoV+[4]) try to reduce bandwidth requirement by predicting user's FoV and streaming only FoV.
- Accurately predicting the user's FoV is challenging.
- The proposed approach tries to solve the issue of bandwidth usage without introducing any viewport prediction error.

[3] Qian, Feng et.al, "Optimizing 360 Video Delivery over Cellular Networks. Association for Computing Machinery", ATC 2016.
[4] Bao, Yanan et.al., "Motion-Prediction-Based Multicast for 360-Degree Video Transmissions", SECON 2017.

Existing Methods: FoV-Only

- It follows the well-known DASH protocol.
- It conducts the user trial to capture their head movements for different genres of the video.
- Linear regression is applied on the recorded user data to predict the viewport for short periods (e.g., 0.5s, 1s, 2s).
- It only fetches the tiles inside FoV, making it more susceptible to anomalies created by prediction error.

Fig. Tiled 360^{o} Video with highlighted FoV.

Existing Method: FoV+

- At any time instance *t* it predicts the viewport for *t+T* using collected movement traces of the user, where *T* denotes the prediction window.
- To deal with prediction error, it fetches redundant part of the frame which is situated outside the predicted FoV in low quality.
- It first predicts the planar FoV in the frame and then a circular part of that FoV is created which adds extra part of the frame around the edges of the planar FoV.

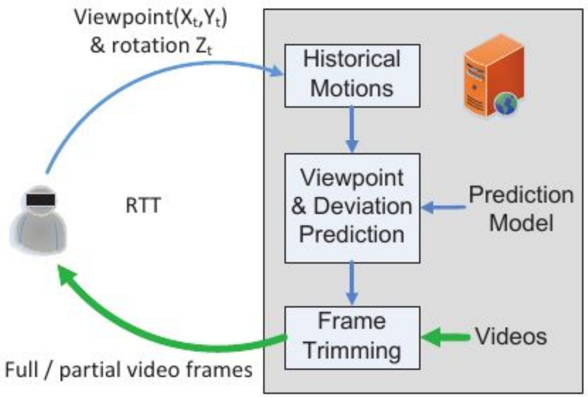

Fig. Working of FoV+[4].

[4] Bao, Yanan et.al., "Motion-Prediction-Based Multicast for 360-Degree Video Transmissions", SECON 2017.

Motivation : Saliency Map

- Saliency refers to unique features (pixels, resolution etc.) of the image in the context of visual processing.
- Saliency map is created by taking the average of feature maps (Colors, Intensity etc.).
- It helps in identifying important regions for proposed approach.

(a) Video frame

(b) Saliency Map

Fig. Saliency map of a snapshot from a soccer match.

Proposed Approach: Content Aware 360° Video Streaming

Saliency Map → Counting Salient Points → Threshold Selection → Saliency Count Lookup → Bitrate Allocation

Fig. Tiles of 360° video denoting normalized number of salient points.

Content Aware 360° Video Streaming: System Architecture

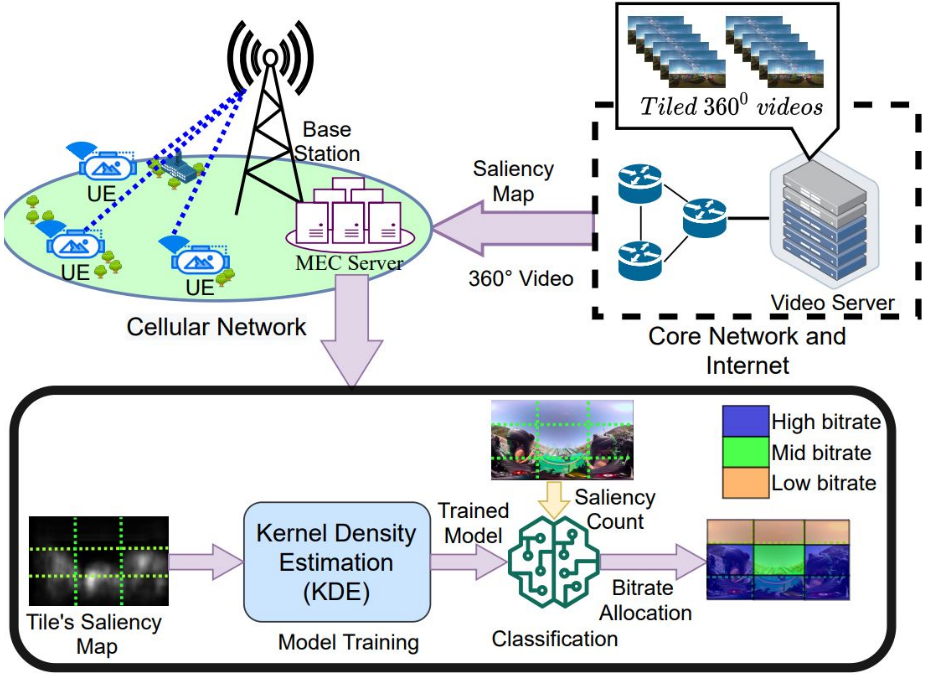

Fig. Architecture of the proposed content aware 360° video streaming framework.

Content Aware 360° Video Streaming: Threshold Selection

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- Value of every pixel of saliency map ranges from 0 to 255.
- Count of salient points in one tile can range have a wide range.
- Saliency counts are not evenly distributed.
- Classification of saliency counts is necessary for bitrate allocation.
- Saliency counts have a many-to-one relationship with available bitrates.

5	210	100	175
190	15	98	185
200	150	65	53
204	190	35	47

Fig. Representation of saliency lookup.

Content Aware 360° Video Streaming: Bitrate Allocation

- The proposed method doesn’t differentiate between the FoV region and the OOS region.
- All tiles in FoV do not necessarily contain the salient regions.

Fig. Tiled video with highlighted FoV.

Results: 360° Video Dataset[1]

- Dataset is derived from 10 standard 360 videos from YouTube with different characteristics.
- 60 seconds parts of the video are extracted from every video.
- It uses convolutional neural network for saliency map extraction.

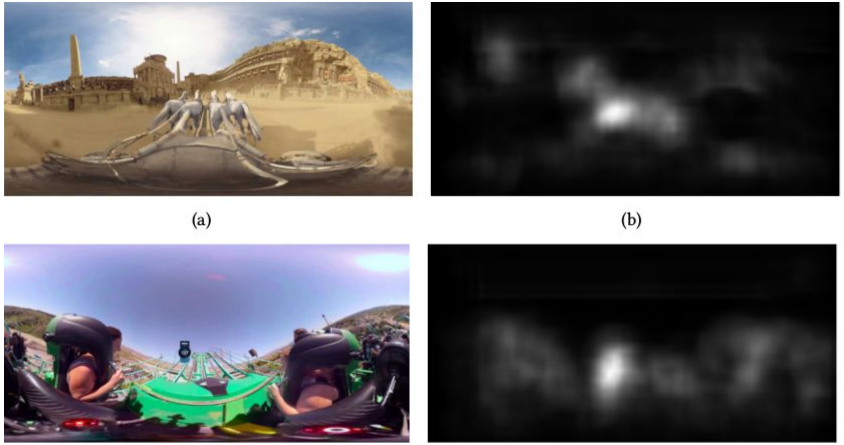
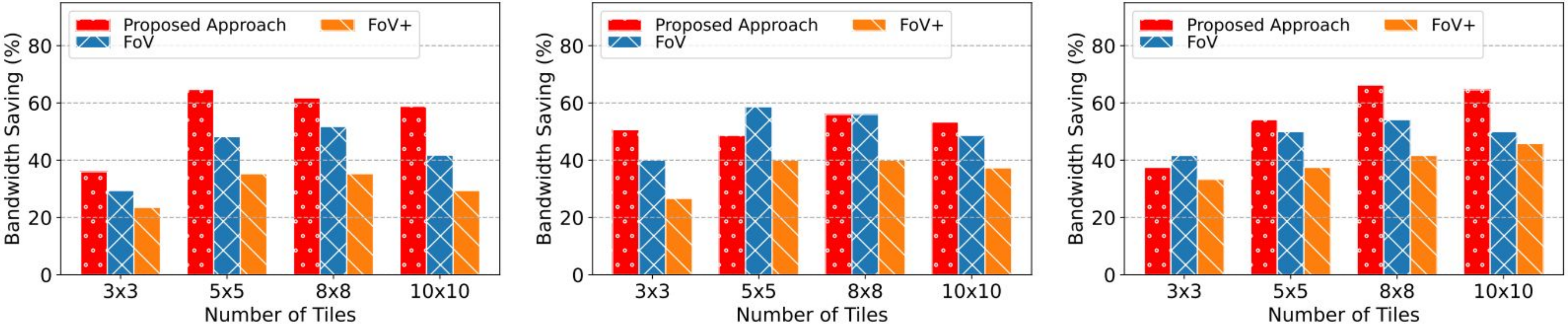


Fig. Illustration of saliency maps of two 360° video frames[1].

[1] Wen-Chih Lo et.al., “360° Video Viewing Dataset in Head-Mounted Virtual Reality,” MMSys'17

Results

- Distribution of salient regions directly affects the bandwidth saving.
- Driving 360 has sparsely distributed salient objects, whereas Kangaroo Island has dense distribution over a large area of the frame.

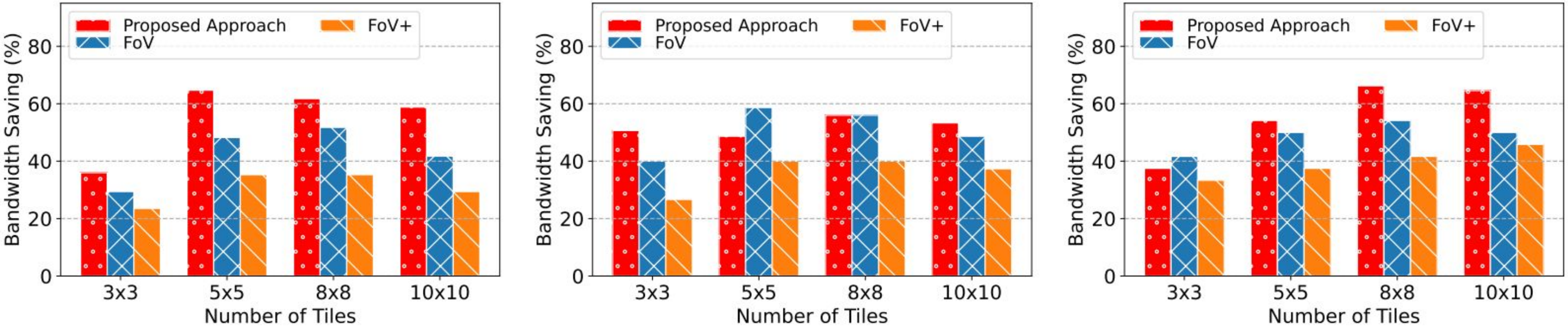


(a) Driving 360° (b) Kangaroo Island (c) Hog Ride

Fig. Bandwidth Saving Comparison for the different videos from the dataset.

Results

- Dense salient object distribution over very small part of the frame in Roller Coaster and Shark Dive Video.



(a) Driving 360° (b) Kangaroo Island (c) Hog Ride

Fig. Bandwidth Saving for the different videos from the dataset.

Results

- Effect of tile variation on bandwidth reduction is different for different videos.

Video	3x3	5x5	8x8	10x10	Original
Driving 360	11 MB	6 MB	6.5 MB	7 MB	17 MB
Kangaroo Island	7.4 MB	7.7 MB	6.6 MB	7 MB	15 MB
Pacman	4.3 MB	4.5 MB	5.4 MB	6.5 MB	10 MB
Hog Rider	15 MB	11 MB	8.1 MB	8.5 MB	24 MB
Roller Coaster	7.7 MB	4 MB	4.9 MB	6.1 MB	16 MB

Fig. Bandwidth reduction of different types of 360° videos for different variations of tiling.

Results

- QA of video created with proposed approach outperforms FoV with huge margin.
- QA of video created with proposed approach outperforms FoV+ without having to predict future FoV.

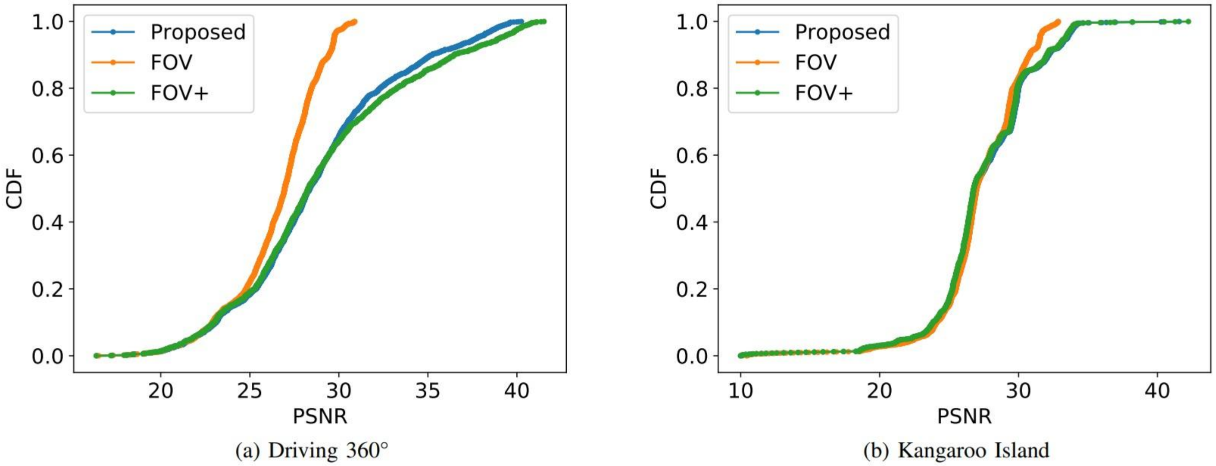


Fig. QA achieved using the proposed solution for the videos in the dataset.

Conclusion

- This work introduces a content-aware adaptive bitrate selection solution for 360° video streaming.
- The proposed solution determines the important video tiles using the saliency map which helps to overcome the dependency on the client feedback for the user’s viewport.
- The results from our extensive experiments show that the proposed solution achieves up to 50% bandwidth reduction as compared to the legacy 360° video streaming.
- The proposed solution saves 15% more bandwidth while maintaining an average 28.5 dB PSNR as compared to the existing solutions.

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Thank You !

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